GPR imaging of lava tubes with the TubeX project

Sanaz Esmaeili, Sarah Kruse, W. Brent Garry, Patrick Whelley, Kelsey Young, Sajad Jazayeri, Ernest Bell

PRESENTED AT:

ABSTRACT

Lava tubes can offer protection for human crews and their equipment on other solar system bodies (such as the Moon or Mars), in particular from radiation threats and extreme surface temperatures.

Developing strategies to locate suitable tubes for human habitation will likely become an important part in planning future space exploration projects.

In the TubeX project, a variety of surface geophysical techniques, such as ground penetrating radar (GPR) have shown the potential to help recognize and map tubes. In this paper, we just focus on the application of GPR in this project, limitations and capabilities.

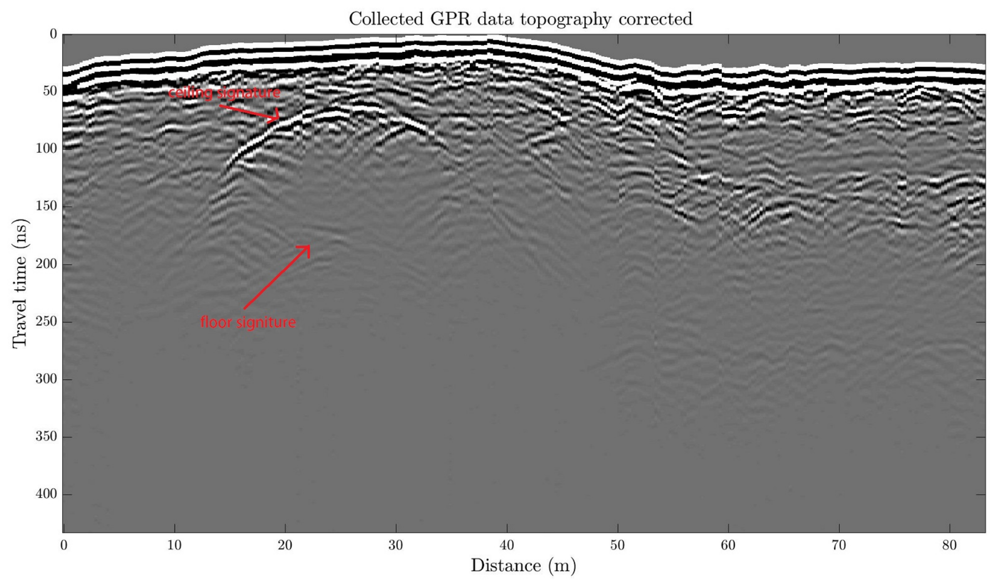
GPR SURFACE DATA COLLECTION

Skull cave

GPR profile crossing Skull Cave (location is line 4 (light blue) on the GIS map in the “Site, Data Acquisition” section). Basic processing steps include dewow, time zero corrections, and frequency filtering.

The cave ceiling reflection is sharp and obvious. There is a weak signature of the floor. In this image the floor is not as the correct depth as the data have not been migrated.

For detailed results after 2D velocity migration and comparing the GPR with LIDAR data please see my other poster (P51E-2925: Migration of ground penetrating radar (GPR) data to image the floor of lava tubes; TubeX project).



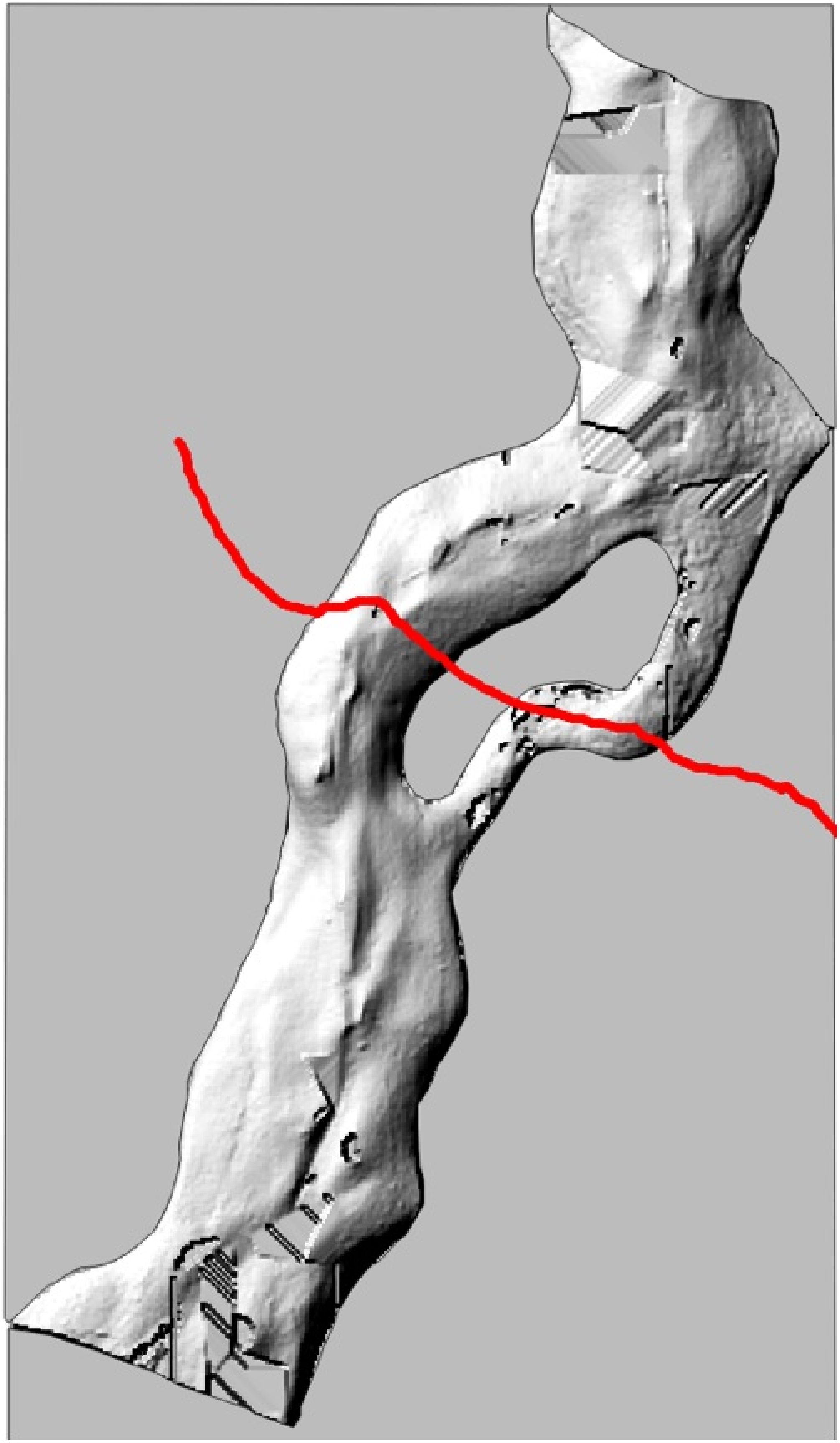
3D view

[VIDEO] https://www.youtube.com/embed/-iUf9Ah35nE?feature=oembed&fs=1&modestbranding=1&rel=0&showinfo=0

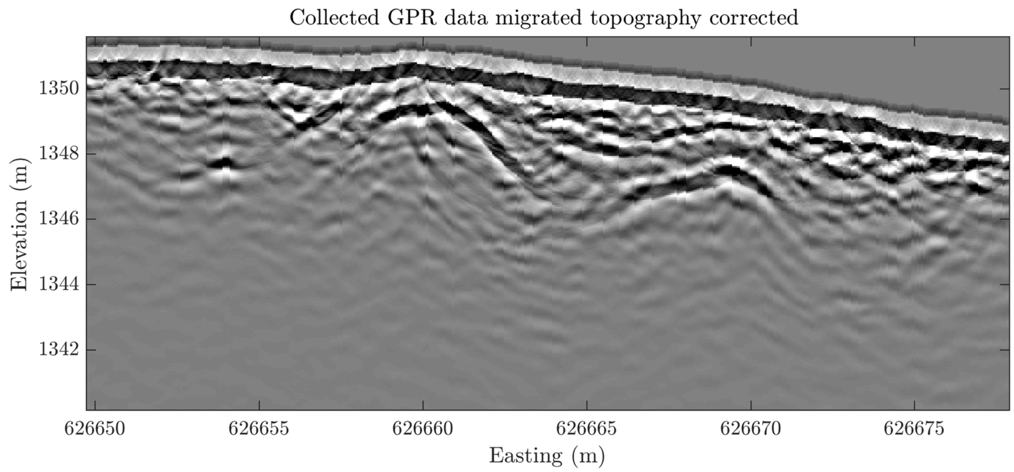
Valentine Cave

The results which are presenting here is for line 29cut at the valentine cave which you can see in the GIS map (black line) in "site, data acquisition" section.

This image is the LiDAR shaded relief images of the tube top, the red line shows the position of GPR profile.



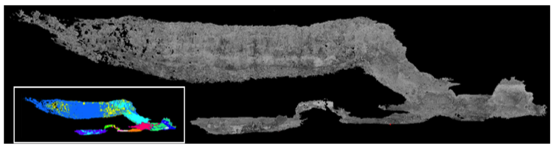
GPR result over this line with basic processing:



GPR MAPPING OF CAVE FLOOR BENEATH ICE

The floor of two rooms in Skull Cave are covered with ice of unknown thickness. LBNM mangers were interested to know the thickness of ice in these rooms. This is a question that GPR can help to answer.

The image below is a LiDAR side view that shows the two different mapped levels in the cave. The ice form the floor of the room with the flat bottom in the deeper level, shown with white/pink and orange in the inset.



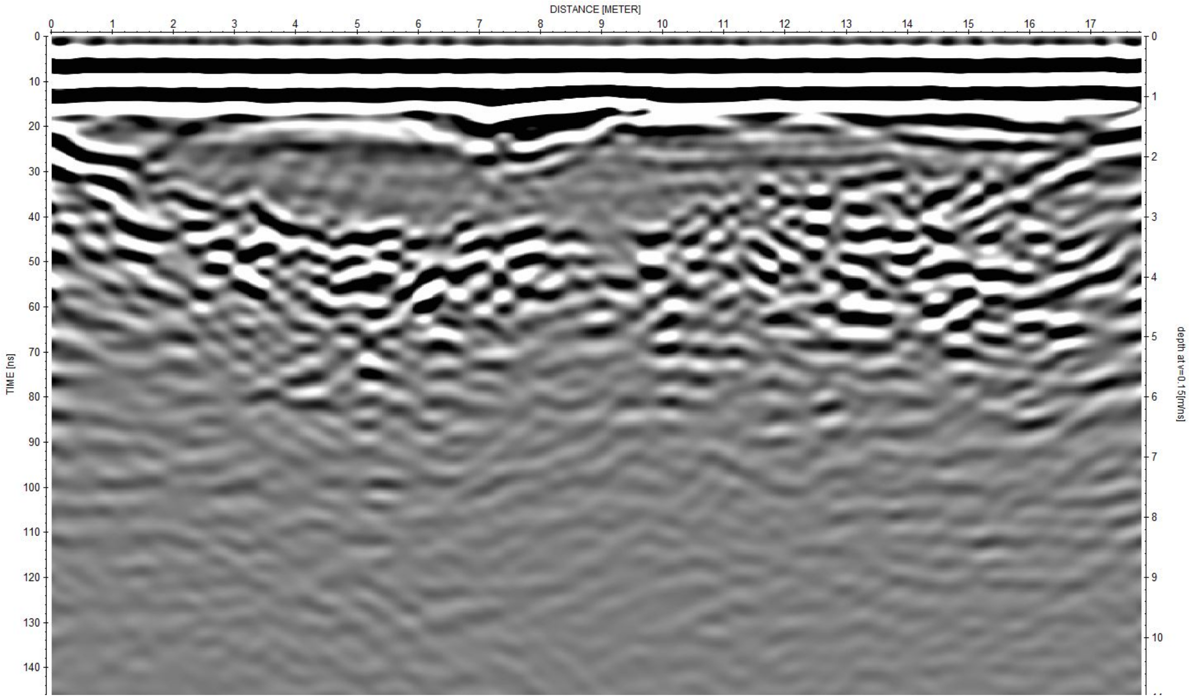
The photo below shows the two levels inside Skull Cave and the stairs that connect them.

This fantastic video, made by LiDAR team, shows the iced floor room (Thanks to Frankie Enriquez for making LiDAR images and video).

[VIDEO] https://www.youtube.com/embed/jhHDNsUpt-Q?feature=oembed&fs=1&modestbranding=1&rel=0&showinfo=0

The photo shows GPR data collection on the iced floor.

Shown below is the GPR result indicating almost 3 meters of ice thickness.


DISTANCE [METER]
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
TIME [ns]
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140
depth at v=0.15[m/ns]
0 1 2 3 4 5 6 7 8 9 10

GPR COMPLEXITY

The GPR profiles over the tubes are, as expected, complex, due to scattering from fractures in roof material and three-dimensional heterogeneities.

The pictures below of the overburden above two different caves show complexity of the material traversed by the GPR wave. The ceiling is fractured; surface topography is rough; large rocks lie on the tubes' floors. All these features complicate GPR returns.

The video below illustrates the complexity of a single GPR pulse traversing a model crossing of Valentine Cave.

[VIDEO] https://www.youtube.com/embed/1vrzx0iPHwA?feature=oembed&fs=1&modestbranding=1&rel=0&showinfo=0

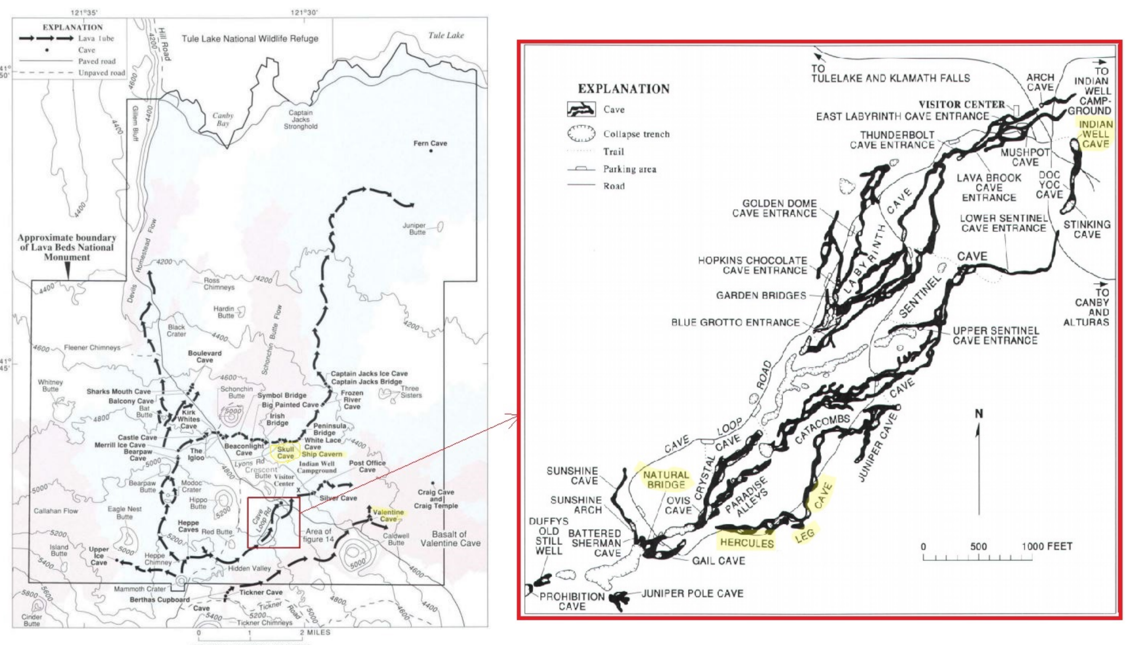
SITE, DATA ACQUISITION

To investigate GPR's capacity and limitations, we use GPR as well as complementary seismic and magnetic surveys, in conjunction with LiDAR mapping of tube interiors at Lava Beds National Monument (LBNM) in northern California, USA. LBNM offers a wide variety of tube geometries and textures.

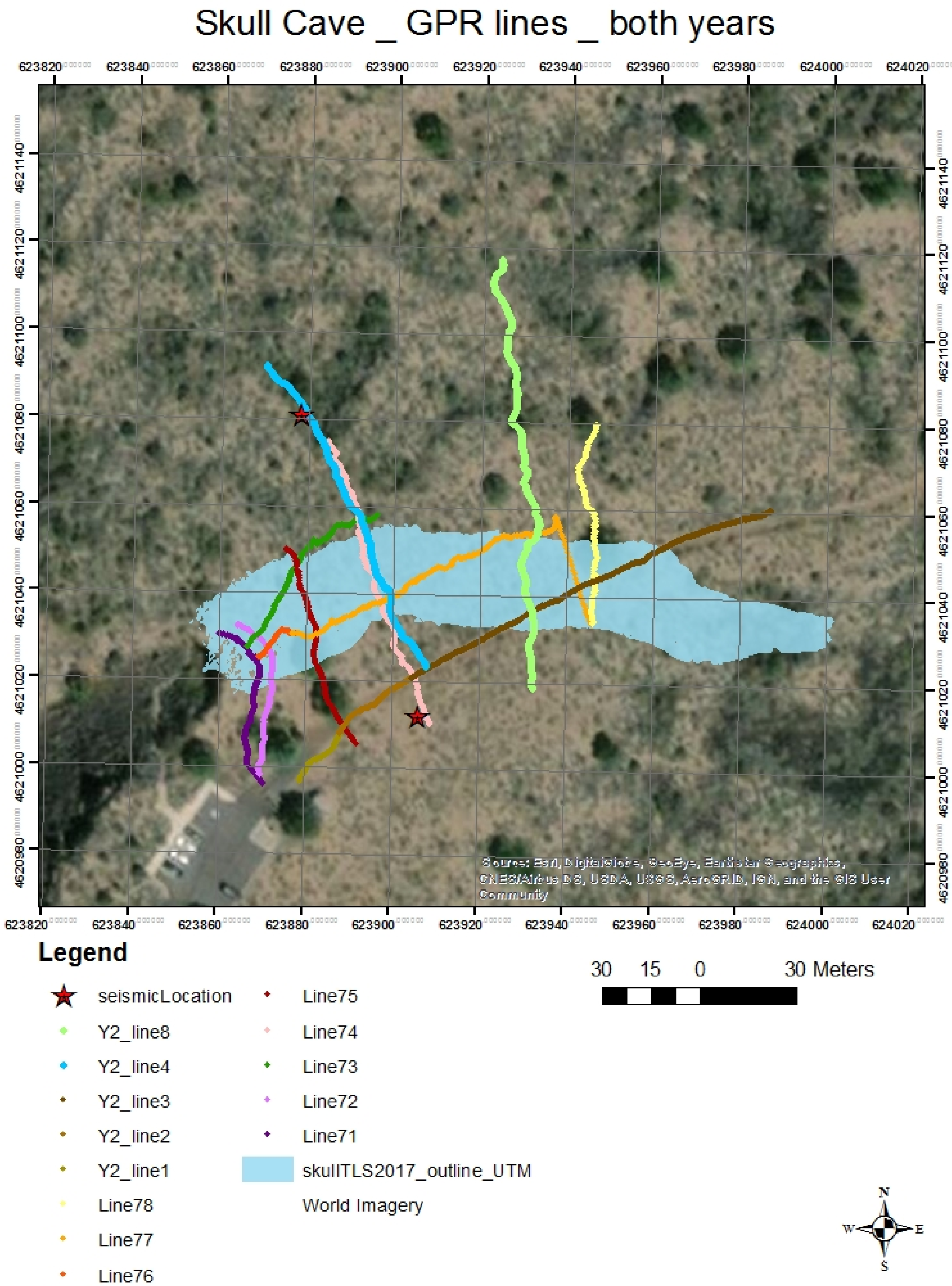
Data collection took place in two campaigns: April-May 2017 and October 2018. For GPR data collection we used:

- The PulseEKKO 100 GPR system from Sensors and Software with 100 MHz antennas and the Ultra receiver in the 2018 campaign
- Trimble R10 RTK GPS positioning

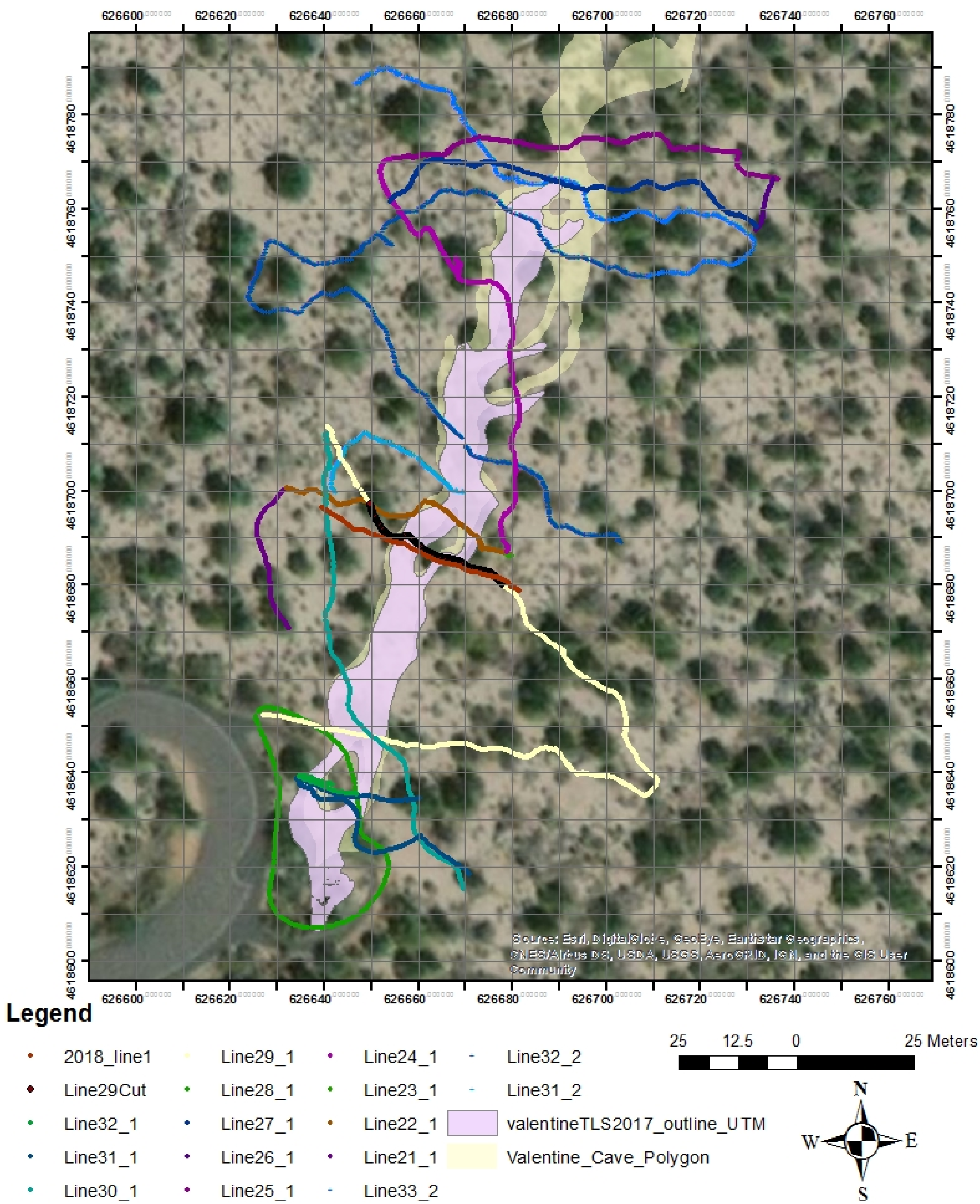
In total we ran GPR profiles crossing Valentine, Skull, Hercules Leg, Indian Well, Natural Bridge, Incline, and Ship & Dinghy caves.



GPR lines for Valentine and Skull caves are shown in the following figures.


Skull Cave _ GPR lines _ both years
623820
623840
623860
623880
623900
623920
623940
623960
623980
624000
624020
4621140
4621120
4621100
4621080
4621060
4621040
4621020
4621000
4620980
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Legend
seismicLocation
Y2_line8
Y2_line4
Y2_line3
Y2_line2
Y2_line1
Line78
Line77
Line76
Line75
Line74
Line73
Line72
Line71
skullTLS2017_outline_UTM
World Imagery
30 15 0 30 Meters
N
W
E
S

All GPR lines over Valentine Cave



SOME PHOTOS

OTHER METHODS/ ACKNOWLEDGEMENTS

For more detailed info about GPR results see

P51E-2925: Migration of ground penetrating radar (GPR) data to image the floor of lava tubes; TubeX project

December 14th - Friday

Time Present: 10:00 AM - 12:00 PM

Convention Ctr, Hall A-C (Poster Hall)

For more info about other methods in TubeX project see

P31H-3799: Developing a Strategy for Lava Tube Exploration by Deploying Field Portable Instrumentation in an Analog Environment

Wednesday, 12 December 2018

08:00 - 12:20

Walter E Washington Convention Center - Hall A-C (Poster Hall)

Contact me:

esmaeili@mail.usf.edu

Acknowledgements

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AUTHOR INFORMATION

Sanaz Esmaeili[1], Sarah Kruse[1], W. Brent Garry[2], Patrick Whelley[3], Kelsey Young[2], Sajad Jazayeri[1], Ernest Bell[4]

1)University of South Florida 2)NASA Goddard Space Flight Center 3) University of Maryland at NASA Goddard Space Flight Center 4) University of Maryland

ABSTRACT

Lava tubes can offer protection for human crews and their equipment on other solar system bodies, in particular from radiation threats and extreme surface temperatures. Developing strategies to survey regions of other terrestrial bodies (such as the Moon or Mars) for tubes suitable for potential habitation will likely become an important part in planning future space exploration projects. A variety of surface geophysical techniques, such as ground penetrating radar (GPR) have the potential to help recognize and map tubes. GPR shows promise for providing high-resolution information on tube geometries. To investigate GPR's capacity and limitations, we use GPR, as well as comparative methods of seismic and magnetic surveys, in conjunction with LiDAR mapping of tube interiors at the Lava Beds National Monument (LBNM) in California, USA. LBNM offers a wide variety of tube geometries and textures.

We have collected 2D GPR profiles and small 3D GPR grids (of parallel 2D lines) with antenna frequencies of 100 and 200 MHz on four lava tubes with different geometries, textures and at different depths. Challenges in recovering tube geometries include wave scattering in fractured rock covering tubes, irregular and 'drippy' ceilings and walls, and blocky floors. Our primary results show that the top of the LBNM tubes can generally be resolved in the GPR data, while resolving the bottom is more challenging. The utility of various GPR processing techniques can be directly assessed by comparing resolved GPR images against the LiDAR-measured tube geometries.